FORECASTING PRECIPITATION IN PERCENTAGES OF PROBABILITY.*

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[Weather Bureau Office, Roswell, N. Mex., Oct. 15, 1920.]

SYNOPSIS.

During the irrigating and alfalfa-harvesting periods the Weather Bureau office at Roswell, N. Mex., issues an amplification of the forecast, in which the probability of rain within 36 hours is expressed in percentages; 100 per cent representing absolute certainty of rain, and 0 per cent absolute certainty of fair weather.

The basis of this method is a series of composite weather maps showing the frequency of precipitation, in percentages, with different types of pressure distribution. These maps are used only for reference, and are used in conjunction with the daily weather map. The percentage of probability of rain, as shown on the composite map, is usually modified—sometimes ignored altogether—in the forecast issued.

Since, during the warmer months of the year, neither rain nor fair weather can often be forecast for this district with absolute certainty, this style of forecast is of value to the farmers in governing irrigation, and also, to a certain extent, in the harvesting of alfalfa.

Some three years ago the writer submitted to the local press a brief article explaining the terms used in weather and temperature forecasting, and therein it was mentioned incidentally that the element of doubt in the forecasts, which at present is roughly approximated by the use of the qualifying words "probably" and "possibly," can usually be evaluated on a numerical scale. This statement was a fortunate or an unfortunate one, depending upon how the matter is viewed, for it seemed to interest several of the clientele of this station, who claimed that such forecasts would be of more value to the agricultural interests of the Pecos Valley than the forecasts as usually worded. In fact, there has been a vague demand for just such forecasts for several years, as the usual inquiry made by the farmers of this district has always been, "What are the *chances* of rain?"

During six months of 1919 a method of forecasting the probability of rain on a scale of 100 was tested, but the forecasts were not published. In these, 100 per cent represented absolute certainty of rain, and 0 per cent, absolute certainty of fair weather. It might be mentioned here that neither 100 per cent nor 0 per cent was employed once during the six months. The results of this test were as follows:

Forecasted probability.	Number of forecasts.	Number of rains.	Actual percentage.
Per cent.			
Above 90	1	1	100
80 to 89	1	1	100
70 to 79	7	6	86
60 to 69	15	11	75
50 to 59	13	8	62
40 to 49	15	8	53
30 to 39	18	6	33
20 to 29	31	7	23
10 to 19	22	4	18
0 to 9	0	.....	.....

There were about 25 days during the six months on which no forecast was made, on account of lack of sufficient data or pressure of other work.

These results are not as satisfactory as could be desired, but it is probable that in the hands of a real forecaster the method might be of value. During the summer of 1920, these forecasts were published on the daily weather bulletin. They were supplementary to the regularly worded forecast, and were placed at the end of the summary of weather conditions. These forecasts early in the season were only for the vicinity of Roswell, but later were extended by permission to the entire agricultural district of the Pecos Valley.

It will have to be confessed that the verification during 1920 was not quite as satisfactory as in 1919. During both seasons too many "intermediate" forecasts were made; when conditions were favorable to rain the probability was usually underestimated, and was overestimated when conditions were not favorable to rain. The average verification of all forecasts of over 75 per cent was 100 per cent, and of all below 15 per cent, 0 per cent.

The basis of this style of weather forecasting is a series of composite weather maps—that is, composite so far as regards pressure, wind direction and 12-hour pressure changes. These maps originally were constructed in 1913–14, and were designed to show the frequency, in percentages, of precipitation and verifying temperature changes over the area comprising Kansas, Oklahoma,

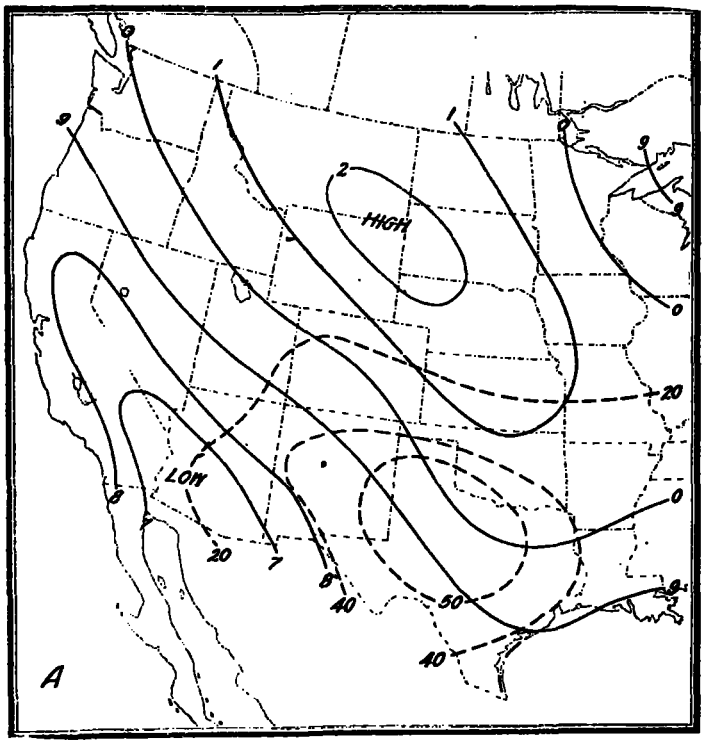

FIG. 1A. (Solid lines, numbered 7, 8, 9, 0, 1, 2, are isobars representing "sea-level" pressures corresponding to barometer readings of 29.7 to 30.2 inches of mercury. Dashed lines indicate percentages of probability of rainfall within 36 hours after the occurrence of the type of pressure distribution indicated.

Texas, Colorado, New Mexico, Utah, and Arizona attending every type of pressure distribution that affected weather and temperature conditions in any part of that area. These composite maps were 98 in number; 62 with a LOW as the predominant pressure feature, and 38 with a HIGH predominant. A number of these have never been completed, owing to an insufficient number of available individual types. The classification was made arbitrarily, to suit the convenience of the writer, after attempts to classify types rationally had proved unsatisfactory. Classification was made according to (*a*) the location of the predominant pressure area, (*b*) its general contour and direction of major axis, (*c*) its direction of travel, and (*d*) the position of the primary opposing pressure feature; (*c*) and (*d*) often were combined. In addition, there were a number of what might be called "special cases."

* The plan of expressing the degree of assumed reliability of a forecast numerically was suggested by Freiherr von Myrbach in the *Meteorologische Zeitschrift* of October, 1913, p. 496–7, and was regularly employed by the Allied military forecasters during the late war (cf. MO. WEATHER REV., December, 1919, 47: 870).—*C. F. T.*

Five of these composite maps were presented in a published paper in 1916.[1]

Of the types represented by the 98 composite maps, no more than 30 need be considered with reference to the Pecos Valley, and of these, no more than 12 are really important. It has, therefore, been practicable to subdivide the types that concern this district without making the number unwieldy, and in a way that materially increases their value.

The three maps presented in figure 1 will serve to illustrate this subdivision. Map A is the original com-

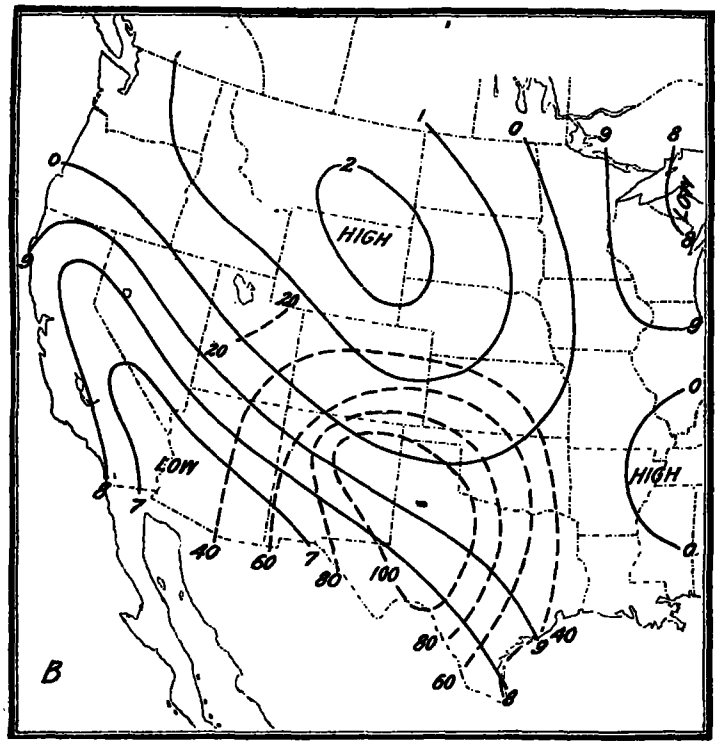

FIG. 1B. (See legend under fig. 1A.)

posite, in which the type is an elongated LOW west of the mountains, with axis northwest to southeast, with its center of depression over or south of southern Arizona, and with a HIGH to the northeast. All the individual maps used in constructing this composite conformed to these specifications. It will be seen that with this pressure distribution, precipitation occurs within 36 hours in eastern New Mexico 50 per cent of the times, and a "50 per cent forecast" is the most objectionable of all. Dividing this type, and using for map B only those cases where general precipitation occurred over eastern New Mexico and western Texas, and for map C only those where no precipitation at all occurred within that area, gives two distinct types, and it further reveals why precipitation occurs with B and not with C.

In B, the actual center of depression is much farther south than in C, a condition favorable to a direct inflow of moist air from the Gulf coast into New Mexico. In C the importation of air is from off Mexico.

Another case is presented in figure 2, where a depression is central over Arizona. Map A is a composite of a number of such LOWS that moved to the left of the normal drift (that is, northeasterly), while B is a composite of a number that moved to the right of the normal path, or southeasterly. In the one case precipitation occurs in the Pecos Valley one time in ten; in the other case nine times in ten. It often happens that when the pressure distribution is similar to that shown on map B, the LOW either remains stationary or moves southward into Mexico.

Referring again to figure 1, if map A were used the forecasted probability of precipitation would most likely be between 25 and 75 per cent. Using maps B and C the forecasted probability would be either below 25 per cent or above 75 per cent, depending upon which of the two types the current pressure distribution most nearly resembled.

Others of the original composites have been divided on a basis of the occurrence or nonoccurrence of precipitation over eastern New Mexico, which has resulted in a reduction of the number of types with which the probability of precipitation is between 25 and 75 per cent.

Improvement in this method of forecasting will result in a further reduction in the number of "intermediate" forecasts, and an increase in the number of forecasts of high and low probability. Perfection in the method would result in the use of but two values, 100 per cent and 0 per cent.

In preparing the composite maps, a base map, 7 by 5 inches, was printed on each side of standard 8.5 by 11 inch loose-leaf sheets, the map occupying the top half of the page. There were thus two maps to the sheet, one being used for charting the frequency of precipitation and the other for verifying temperature changes. The average 12-hour pressure changes and most frequent

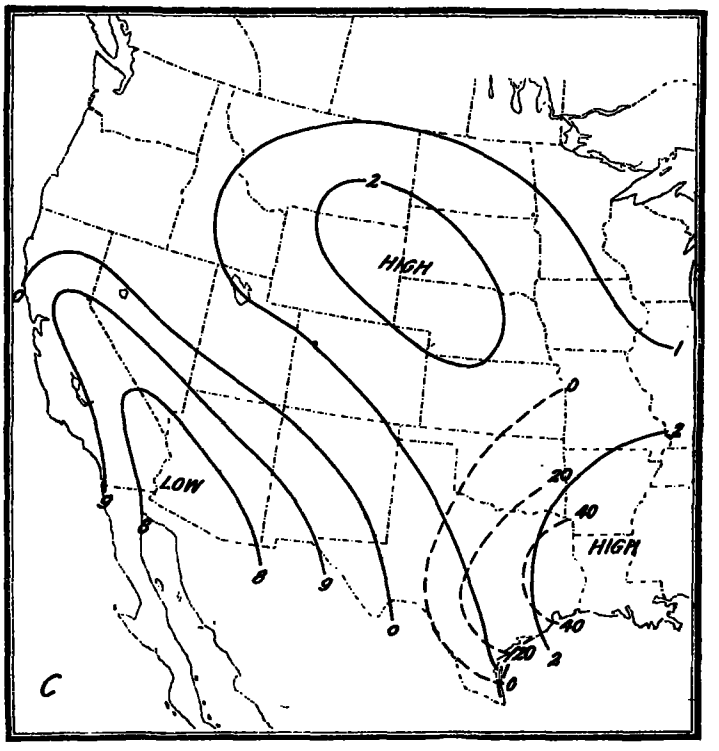

FIG. 1C. (See legend under fig. 1A.)

wind direction were also entered in cases where these are vital. The lower half of each page was reserved for typewritten notes, which, in a few cases, fill the alloted space. These notes are mostly personal observations on the results of variations from type.

In addition, a large number of individual maps have been copied and classified under the various types, and have been so cross-indexed that a LOW or HIGH appearing on any one of them can be followed from the time it first appeared within the United States until it passed east of the Mississippi.

[1] Hallenbeck, Cleve: Precipitation over the southeast Rocky Mountain slope. MO. WEATHER REV., June, 1916, 44: 341-342.

It might be mentioned here that, since each composite map was constructed with reference to the position and general contour of the predominant pressure area (or areas, in a few cases), the pressure gradient on the composite tends to "flatten out" with increasing distance from the predominant HIGH or LOW. For this reason the pressure usually was not charted east of the Mississippi.

In forecasting, these maps are used only as a basis at most, and the probability of precipitation or of verifying temperature changes, as indicated thereon, is not often accepted at its face value. General and local

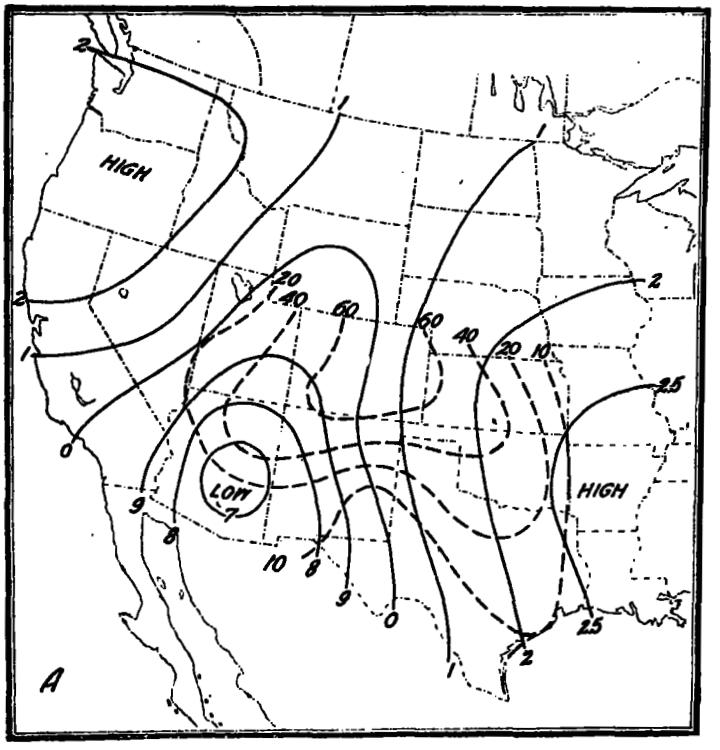

FIG. 2A. (See legend under fig. 1A.)

conditions usually are such as to justify modifying the indicated probability, sometimes materially; and frequently, especially in summer, the pressure distribution is so irregular, with no well-defined high or low areas, that the current weather map can not be referred to any of the classified types.

The method is no more empirical or statistical than the usual method; the principal difference is in the wording of the forecast. It requires the same careful analysis of the prevailing meteorological conditions—or as careful analysis as the fragmentary data and the limited time at the forecaster's disposal permit. It is, as has been stated by others, the forecaster's personal opinion regarding the chances of verification of a rain forecast or the nonverification of a fair weather forecast.

The use of the terms "fair," "generally fair," "possibly rain," "probably rain" and "rain" is approximately equivalent to forecasting the probability of rain on a scale of 1 to 5, and the writer employs these terms, as a rule, for precipitation probabilities of 0 to 5 per cent, 6 to 15 per cent, 16 to 30 per cent, 31 to 75 per cent, and above 75 per cent, respectively.

Precipitation forecasting for this district is seriously handicapped by the lack of weather reports from south of the latitude of Roswell. In the types of pressure distribution that are most productive of rain in the Pecos Valley, the center of the low pressure area, and frequently the major portion of the entire cyclone, is over Mexico, where its exact location and probable future movement can only be guessed.

In addition, the marked influence of the topography of this district adds another complicating factor, which makes forecasting for the comparatively level eastern half of the United States a simple problem in comparison to forecasting in the elevated and diversified districts of the western highlands.

There probably are no more than 10 days during the warmer half of the year when fair weather can be forecast for the Pecos Valley with certainty, and no more than 40 such occasions during the colder half of the year. Precipitation can not be forecast with certainty more than 6 times in the average year. This leaves at least 300 days in each year, or 5 days in 6, for which the element of doubt, in some degree, is present in the forecast.

Knowing this, the farmers of this district naturally wish to choose occasions for certain operations when the rain hazard is least. In the cutting and curing of alfalfa, most of them will accept a risk of 20 per cent—a good deal, however, depends upon the state of the crop, the press of other work, etc.

But it is in irrigation that this style of forecast is of most value. Irrigation in the Pecos Valley is done chiefly from artesian wells, each farm being an independent unit, with its individual well. The farmer can, therefore, use the water as he chooses, without having to wait for specified dates as is the case in irrigation from community canals. He can make every good rain of the summer take the place of an irrigation, and those who watch the forecasts usually suspend or postpone irrigation when the

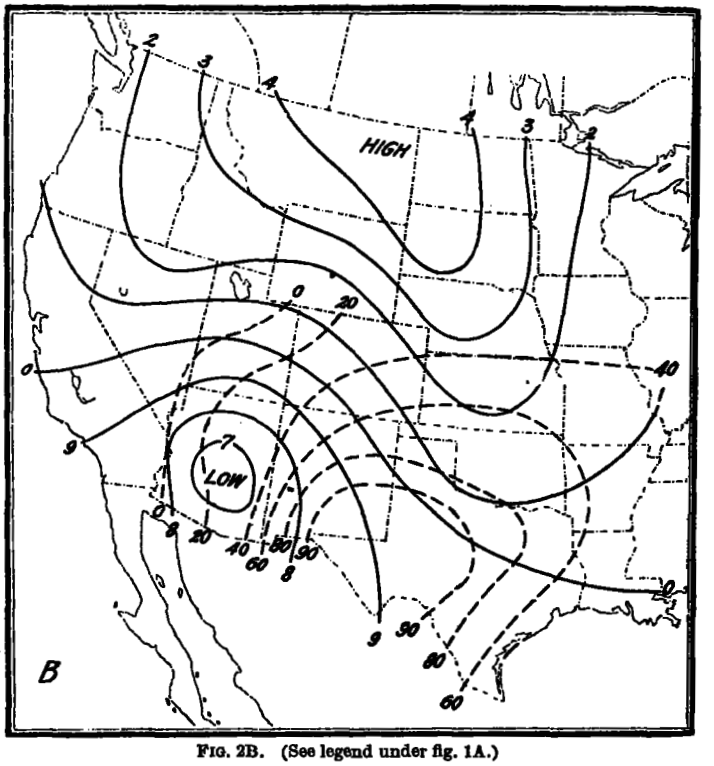

FIG. 2B. (See legend under fig. 1A.)

probability of rain is as high as 50 per cent, and often when as low as 25 per cent, provided the crops are not in immediate need of water. If the rain fails to materialize, they still have the water right at hand for irrigation. At the present time these farmers have a view only to the saving of time and labor, but the progressive extension of the farming area will within a few years reach the point where conservation of the artesian water will be necessary, and when that time arrives the precipitation forecasts for the Pecos Valley will be of more value than in any other district of equal size within the United States.